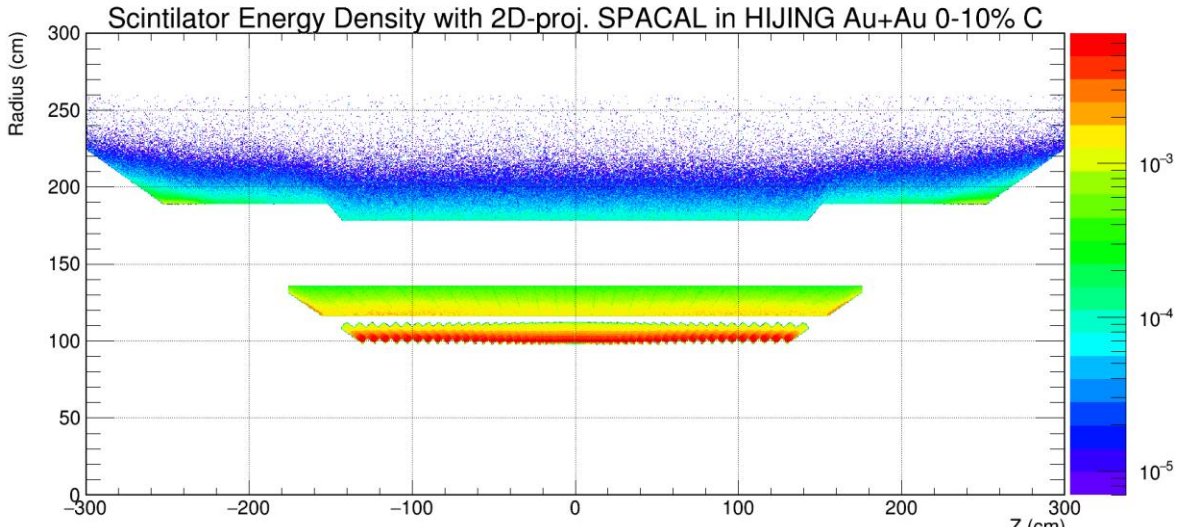
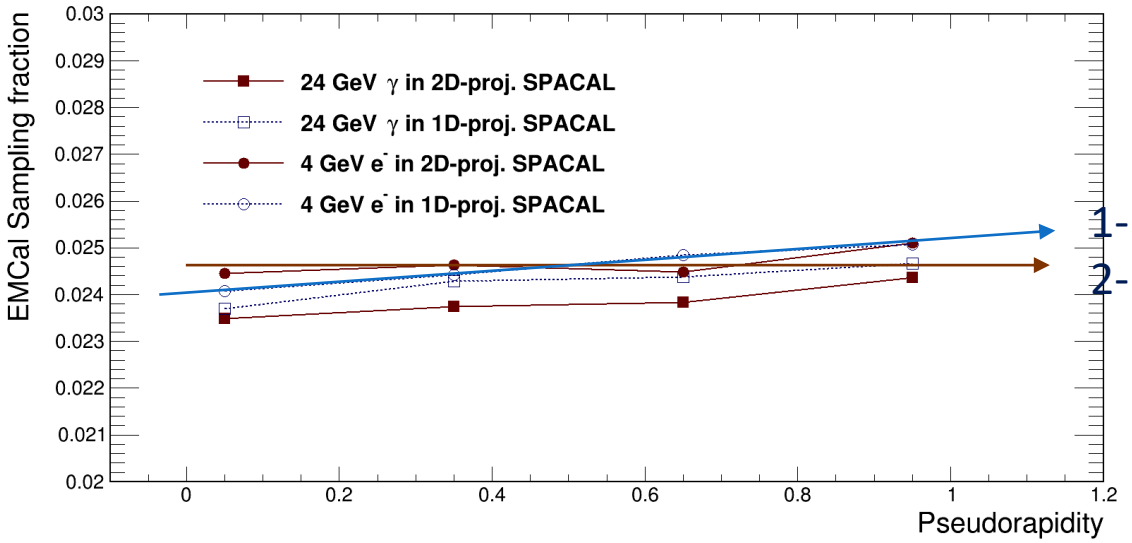
Prototype-3 simulation

Jin Huang (BNL)

What we previously learned

Expectation from sPHENIX pre-CDR simulations: Sampling fraction





1-D SPACAL

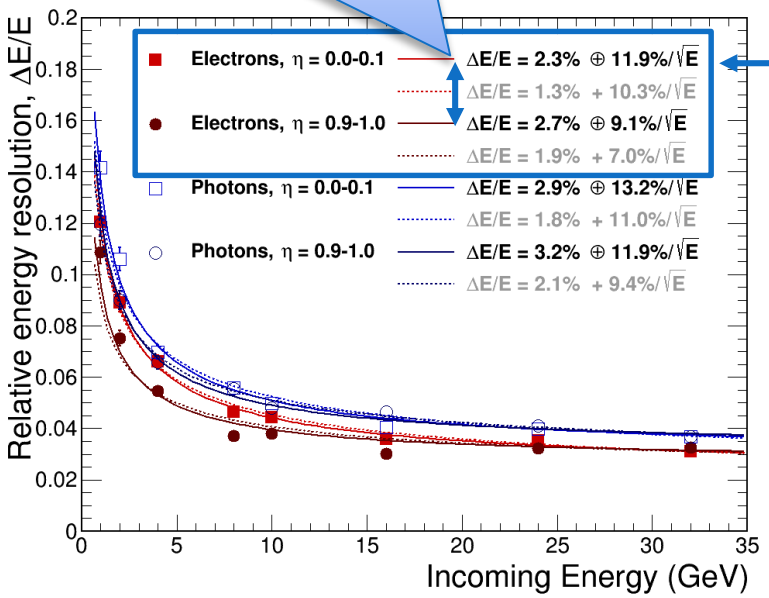
2-D SPACAL

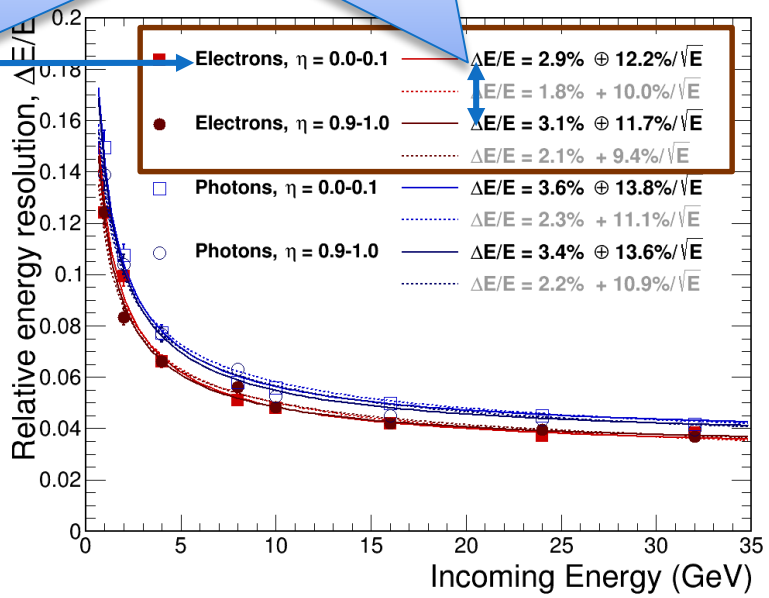
Expectation from sPHENIX pre-CDR simulations: Resolution

Significant improve in stat. term from High sampling fraction and frequency

Larger constant term expected from Variation in sampling fraction VS depth

Consistent performance between forward And central blocks





1D SPACAL, No SVX,
Pedestal noise (2ADC), photon fluctuation (500e/GeV)

2D SPACAL, No SVX,
Pedestal noise (2ADC), photon fluctuation (500e/GeV)

Prototype3 EMCal -> sPHENIX simulation

Introduced by three pull request:

- https://github.com/sPHENIX-Collaboration/macros/pull/44
- https://github.com/sPHENIX-Collaboration/coresoftware/pull/231
- https://github.com/sPHENIX-Collaboration/calibrations/pull/17

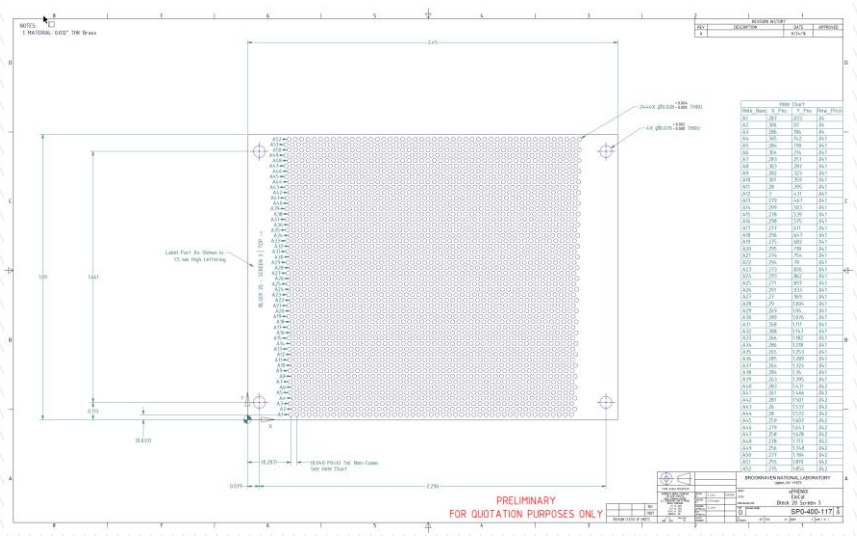
Single macro to run (after nightly build):

- https://github.com/sPHENIX-Collaboration/macros/blob/master/macros/prototype3/Fun4All_G4_Prototype3.C

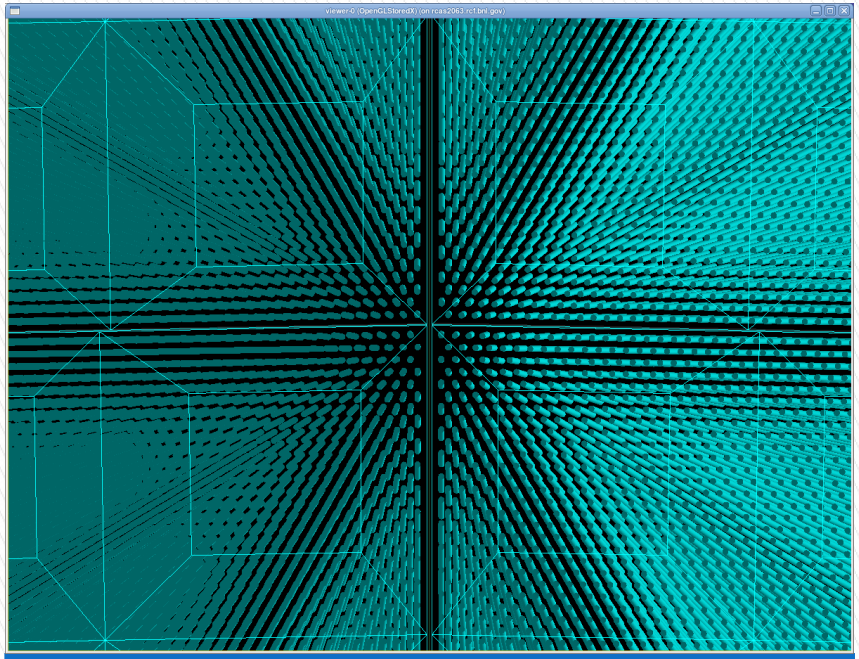
From drawing to simulation

One major head up, Prototype3 has 15% less fiber than pre-CDR simulation:

- Prototype3 fiber for 2x2 block = 52*47 = 2444 (criteria: 1mm spacing at narrow end)
- Pre-CDR fiber for 2x2 block = 60*48 = 2880 (criteria: match sampling fraction with 1-D)

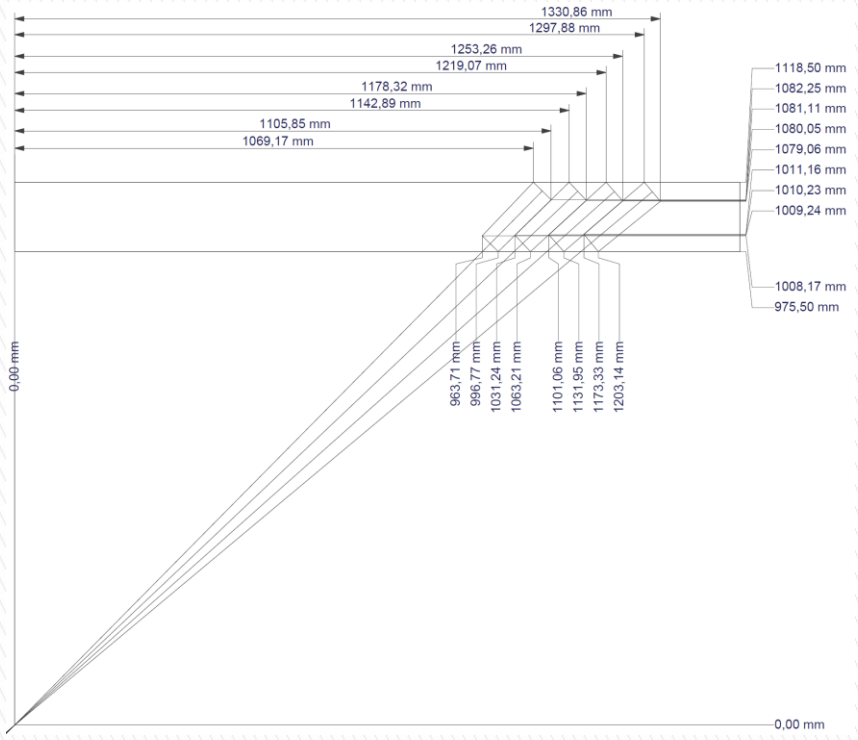


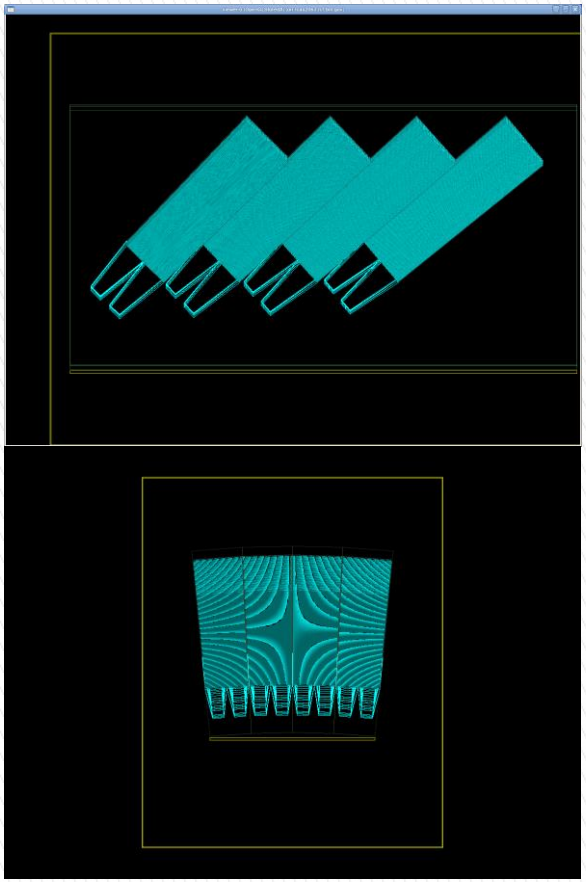
Drawing – Fiber layout



Geant4 simulation

From drawing to simulation

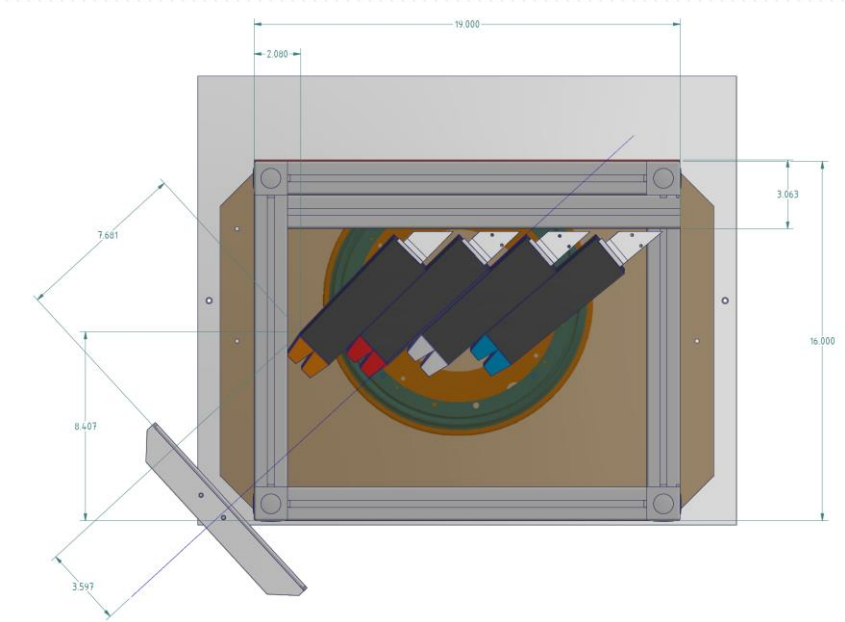


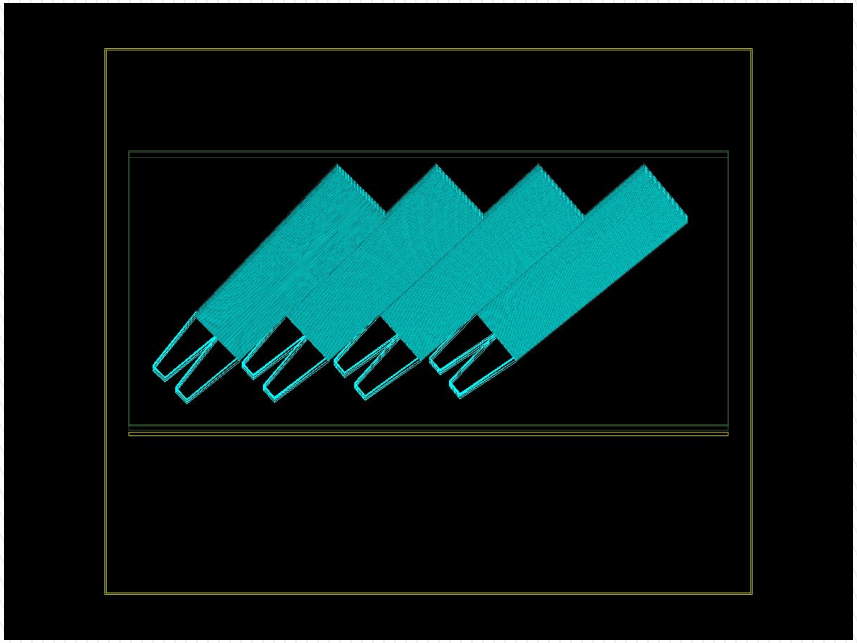


Drawing - Block size

Geant4 simulation

From drawing to simulation

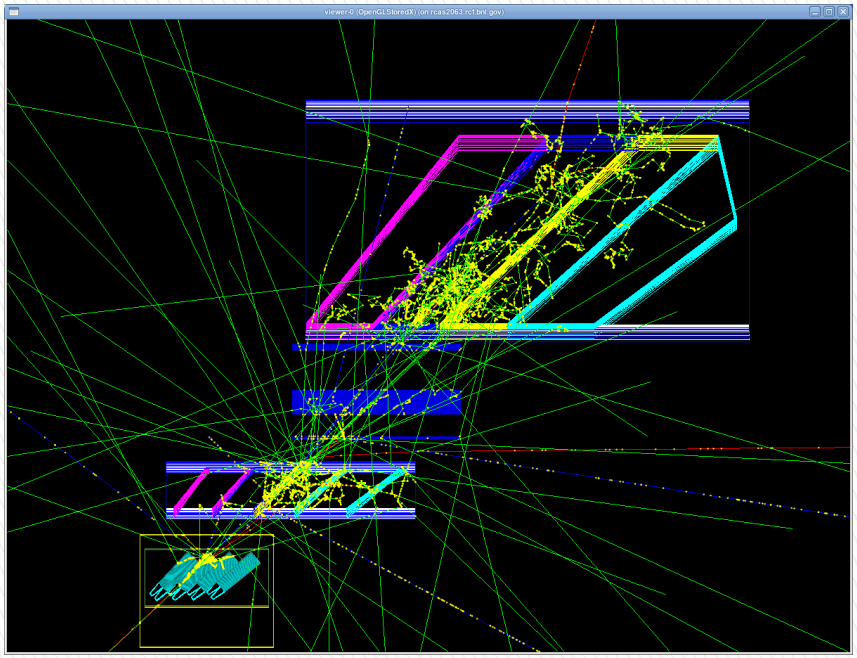




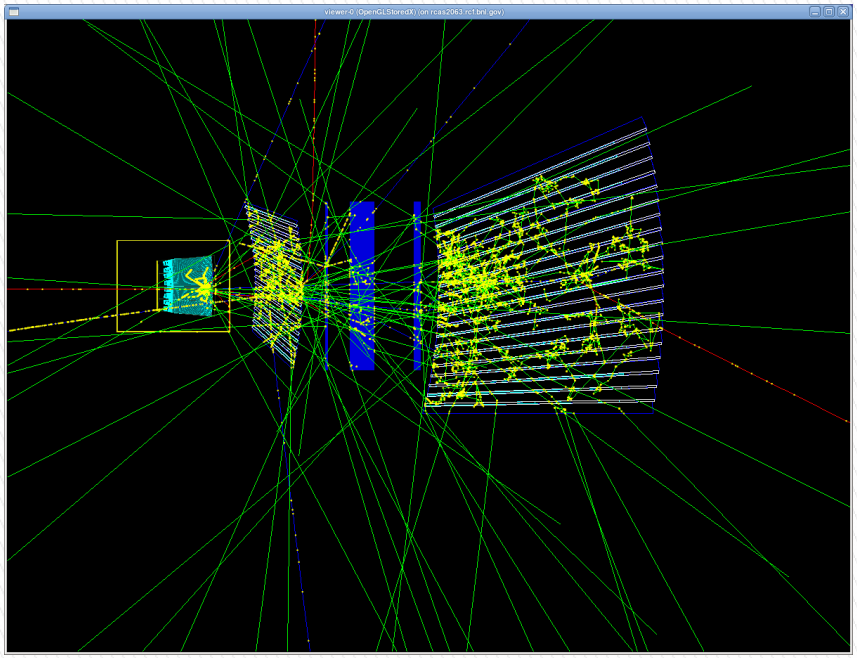
Drawing – Module in enclusure

Geant4 simulation

Put it all together – “typical” Simulation 32 GeV pion

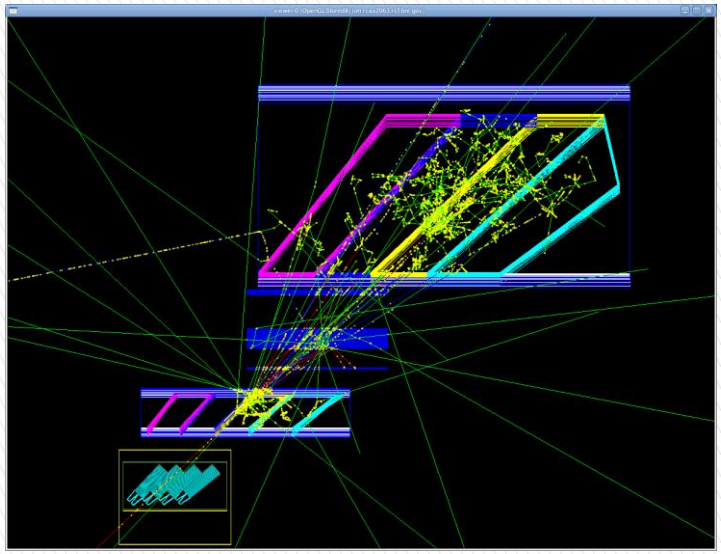


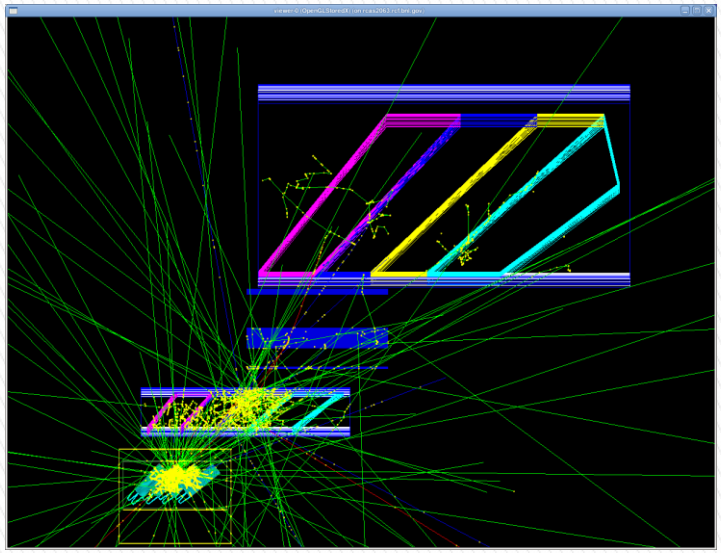
Simulation Top View

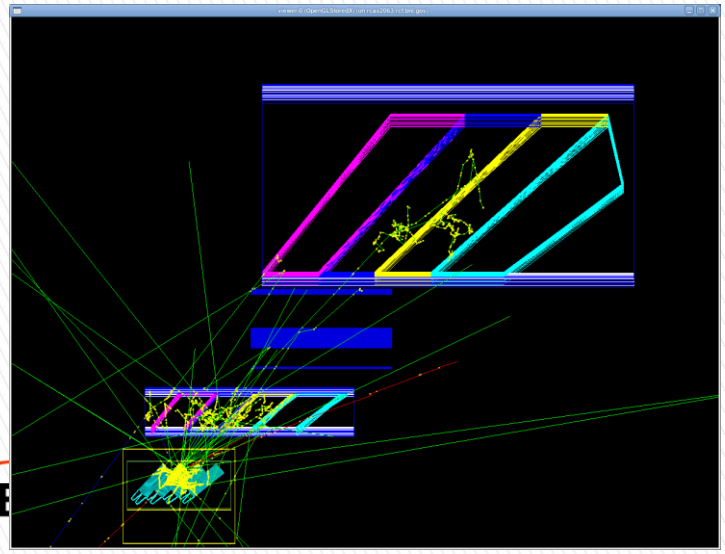


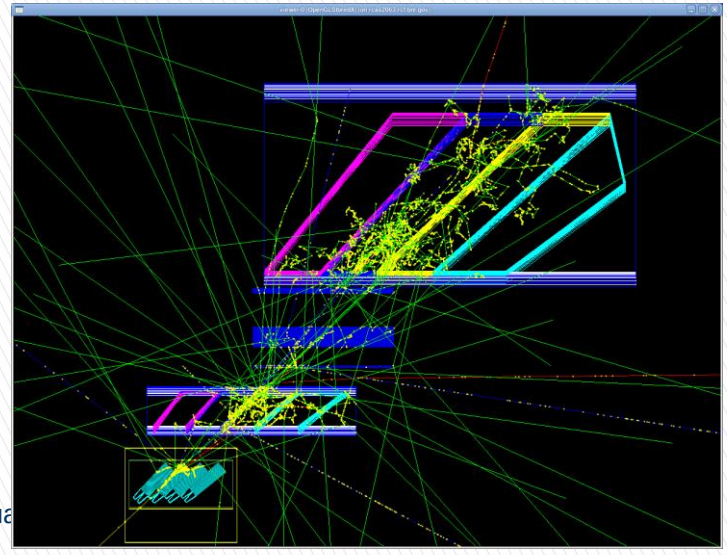
Simulation Side View

Put it all together – What most event looks like

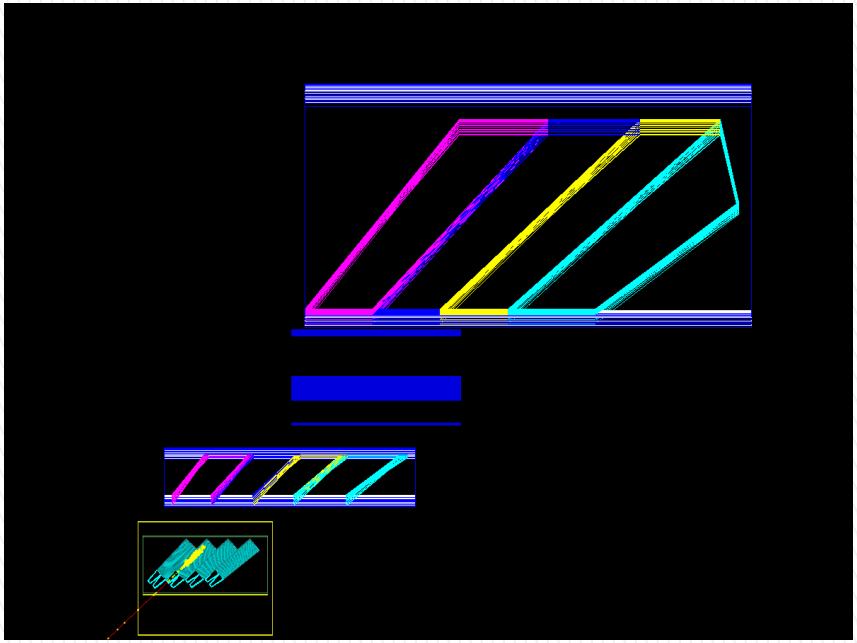




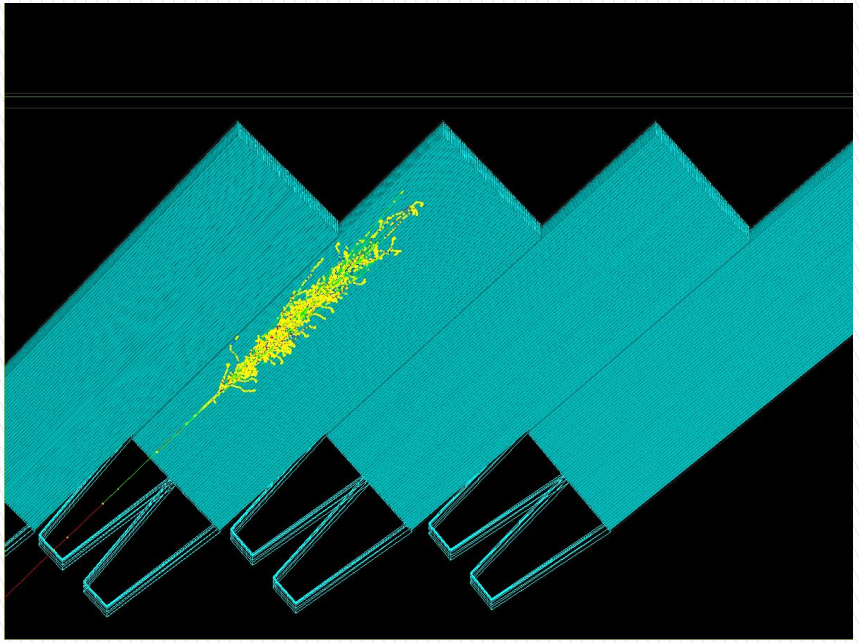




Put it all together – “typical” Simulation 32 GeV electron



Simulation Top View



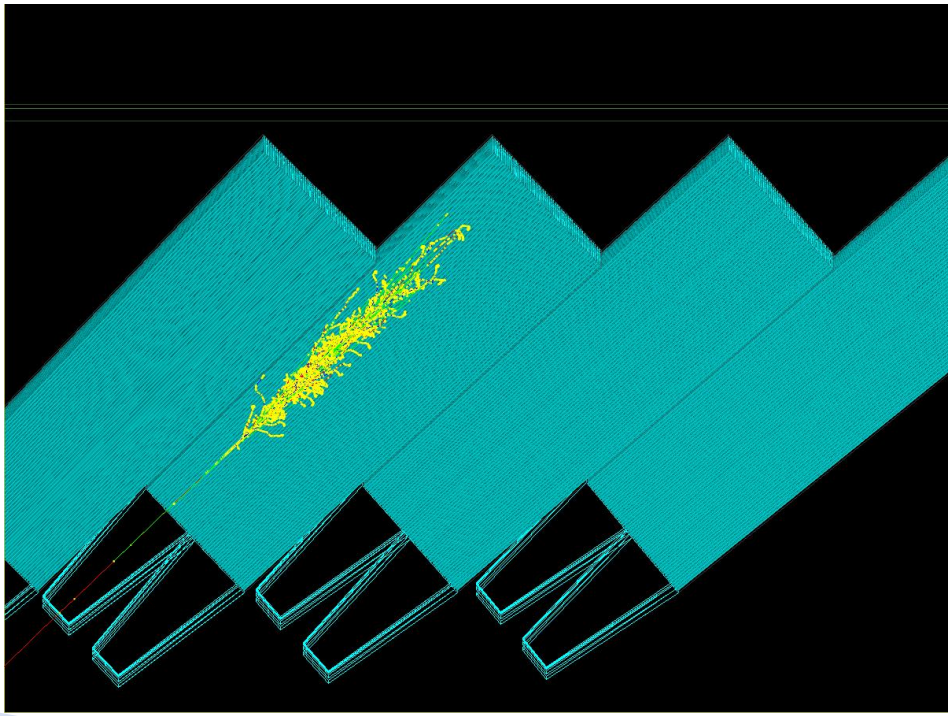
Simulation EMCal View

Performance checks

- https://github.com/sPHENIX-Collaboration/macros/pull/44
- https://github.com/sPHENIX-Collaboration/coresoftware/pull/231
- https://github.com/sPHENIX-Collaboration/calibrations/pull/17

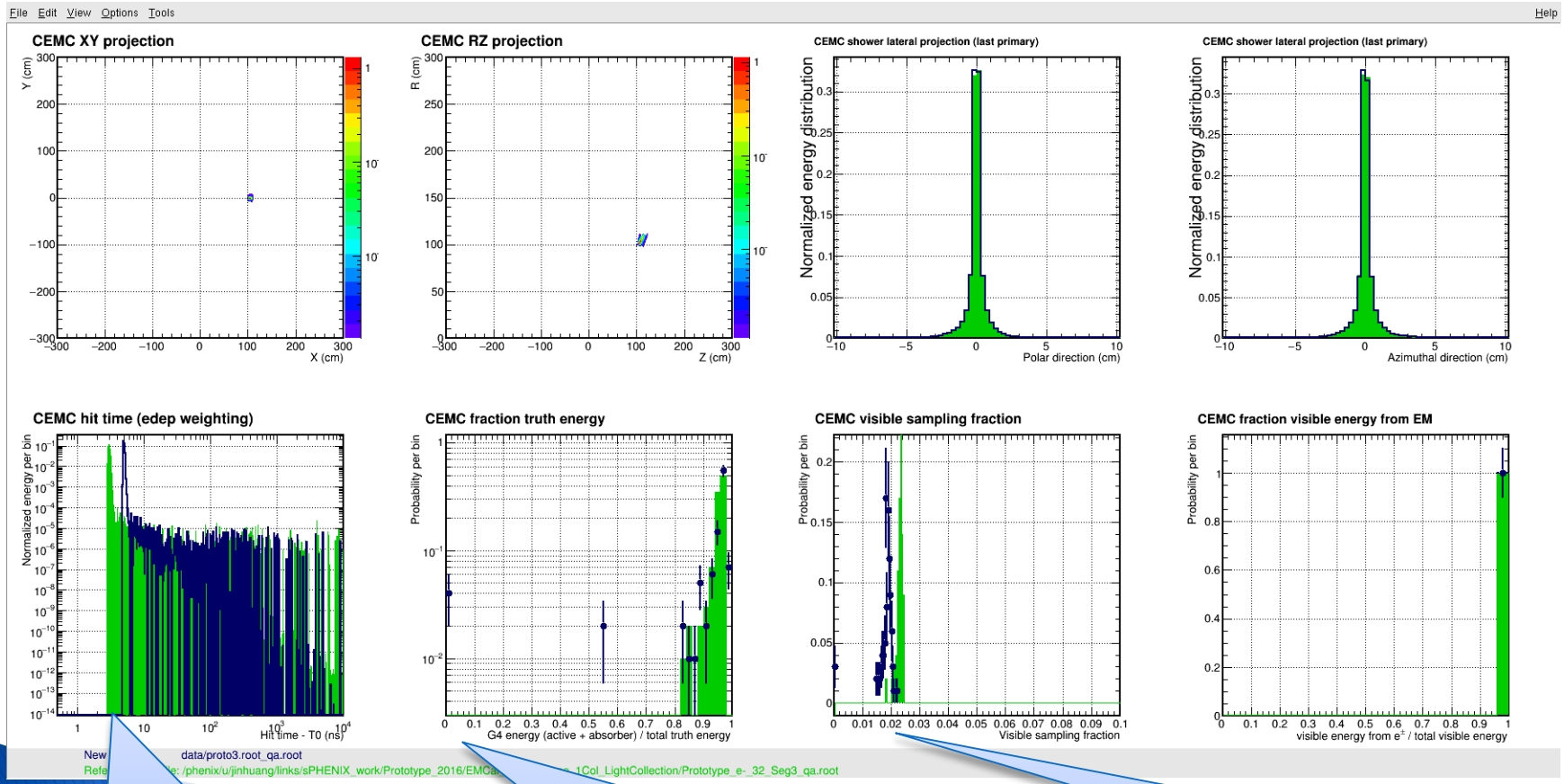
Configuration1 simulated

- Flat light collection efficiency
- Shoot to edge between two towers
- Tilt EMCal 0 degrees vertically



Standardized quality checks

Data point : Prototype3, 32 GeV electron, 0-degree tilt (Configuration1)
Shade: Prototype2 , 32 GeV electron , 0-degree tilt



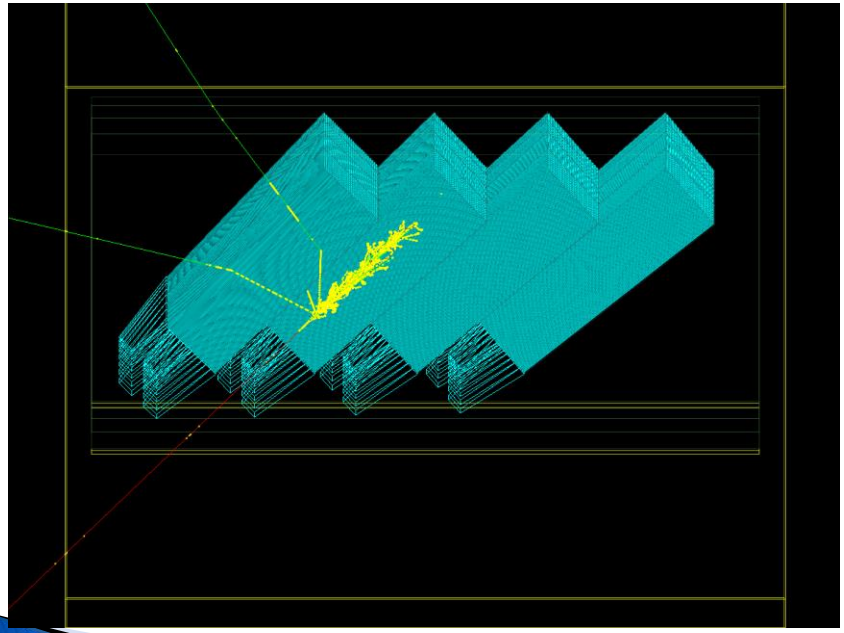
Longer flight path R/Sin(theta)
→ later hit time by a few ns

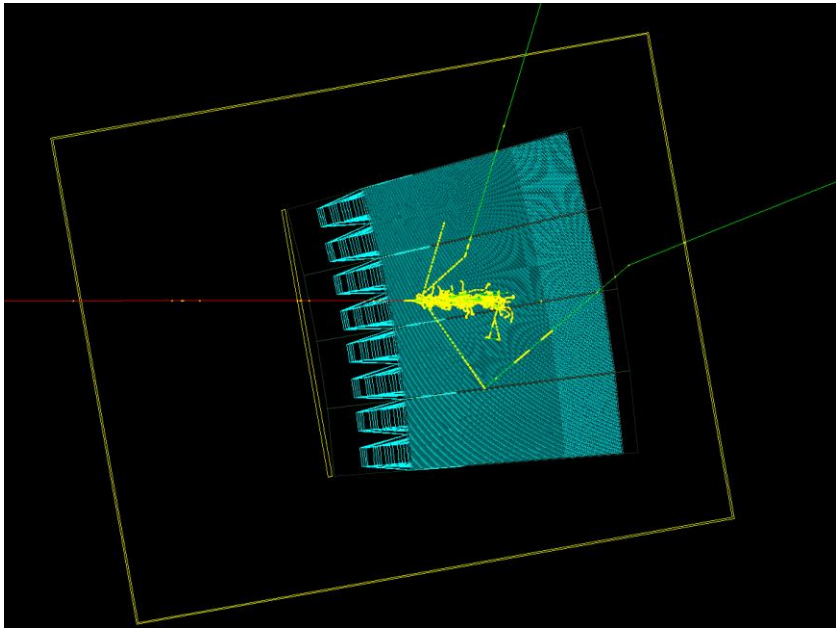
Some leakage due to choice of indenting angle
(Particle goes through exact gap between blocks)

Signification lower sampling fraction!!
Prototype 3 has 15% less fiber than pre-CDR

Configuration2 simulated

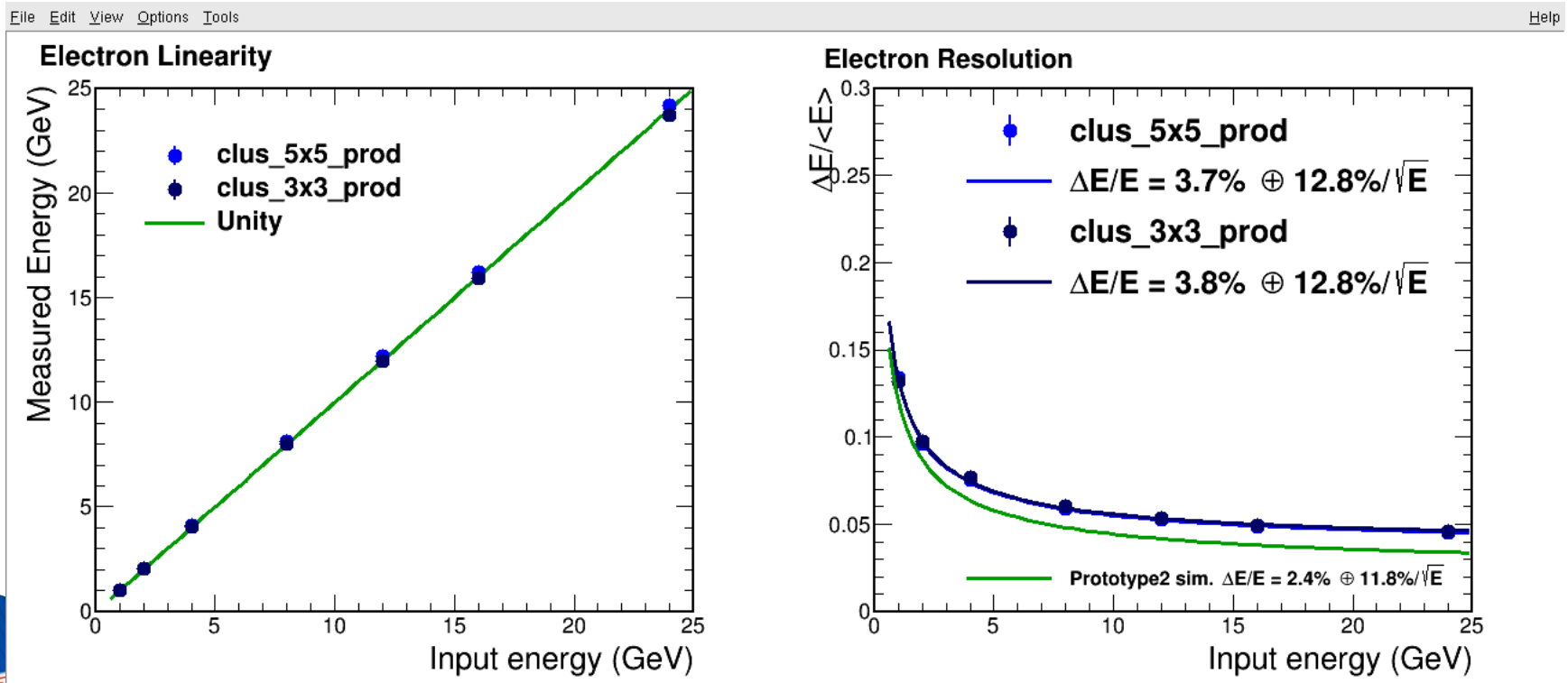
- Flat light collection efficiency
- Shoot to center of one tower
- Tilt EMCal 10 degrees vertically ← add in a tilt avoid perfect-geometry channeling





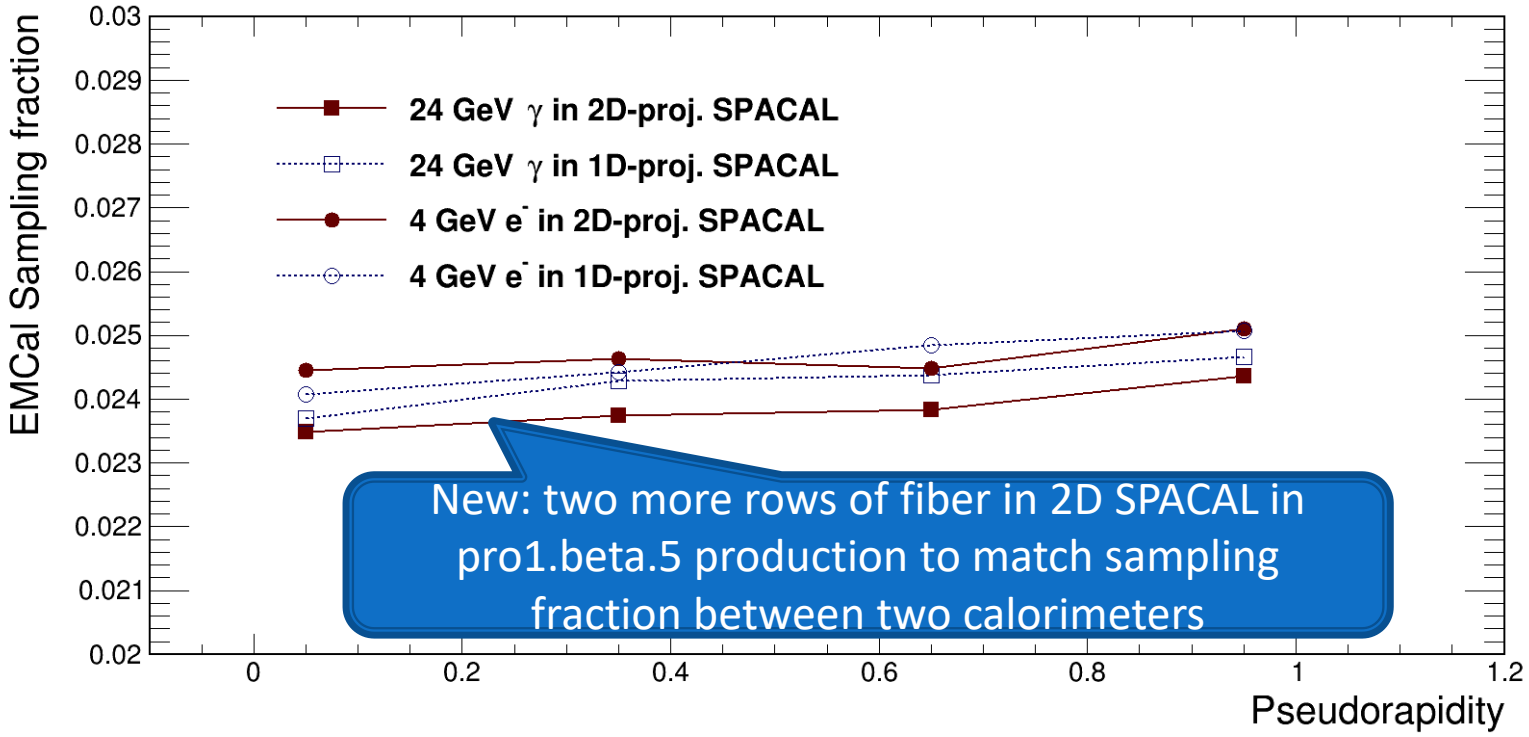
Configuration2 simulation result

- Prototype3 are expected to have higher intrinsic stat. and constant terms:
- 15% less fiber leads to increase of stat. term from 11.8% -> 12.8%
- Some composition of less fiber and expected sampling fraction variation leads to constant term from 2.4% -> 3.7%



Extra information

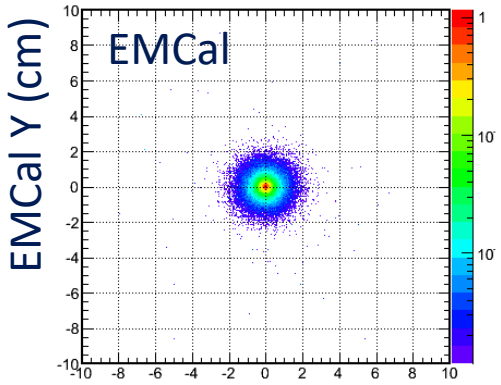
Sampling Fraction

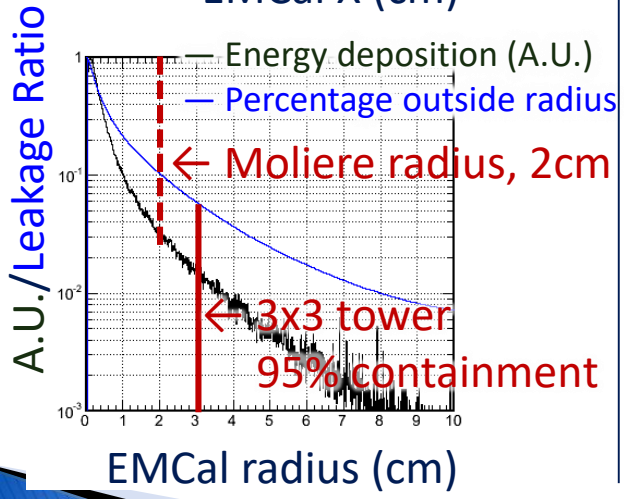


/direct/phenix+sim02/phnxreco/ePHENIX/jinhuang/sPHENIX_work/single_particle/DrawEcal_DrawSF.pdf

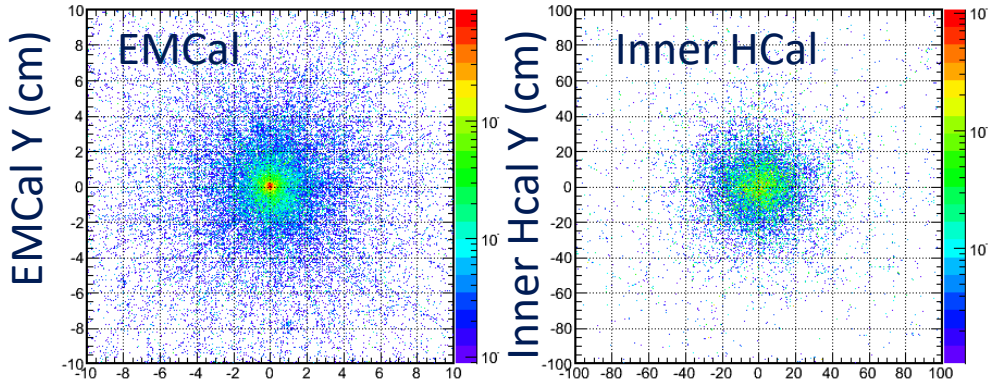
Lateral extension of shower

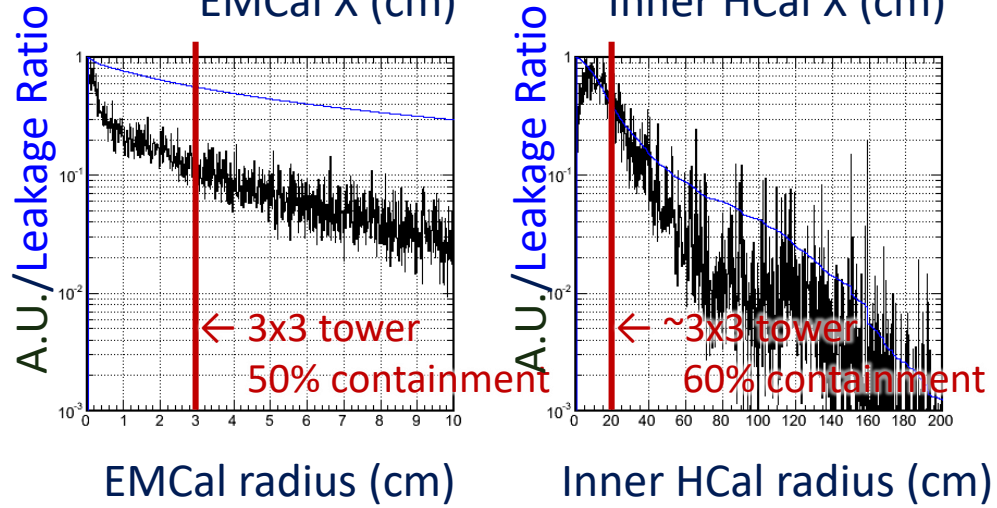
4 GeV Electrons



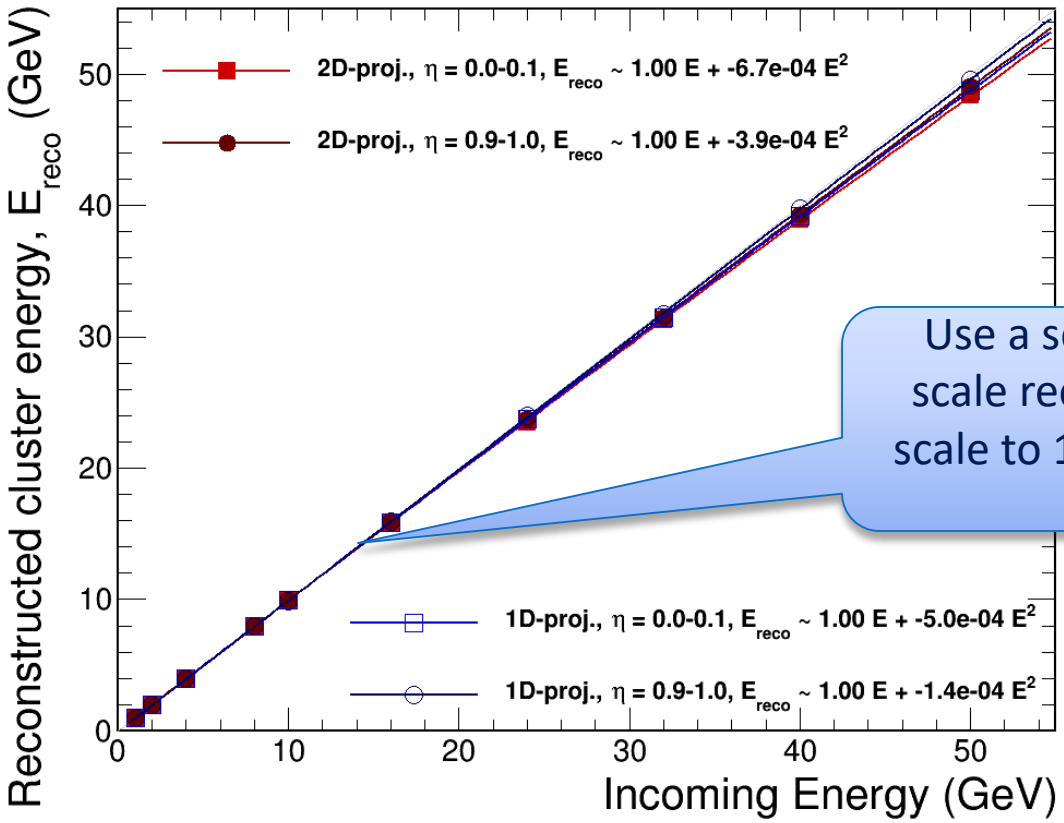


4 GeV Pions, that **passed E/p electron-ID cut**





Linearality – double checking



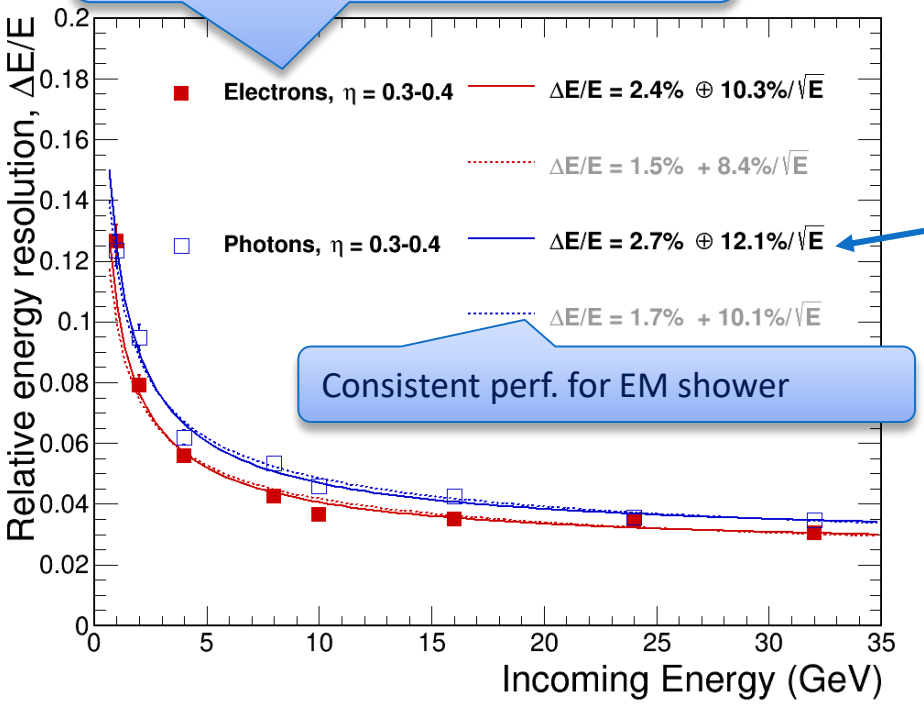
Use a scale correction to scale reconstructed linear scale to 1 individual at each eta region

Energy resolution VS test beam

Geant4 sim QGSP_BERT_HP + light yield model (Geant4 default Birk)
Pedestal noise (8pe), photon fluctuation (500pe/GeV), Zero sup (16pe/32MeV), Graph Clusterizer

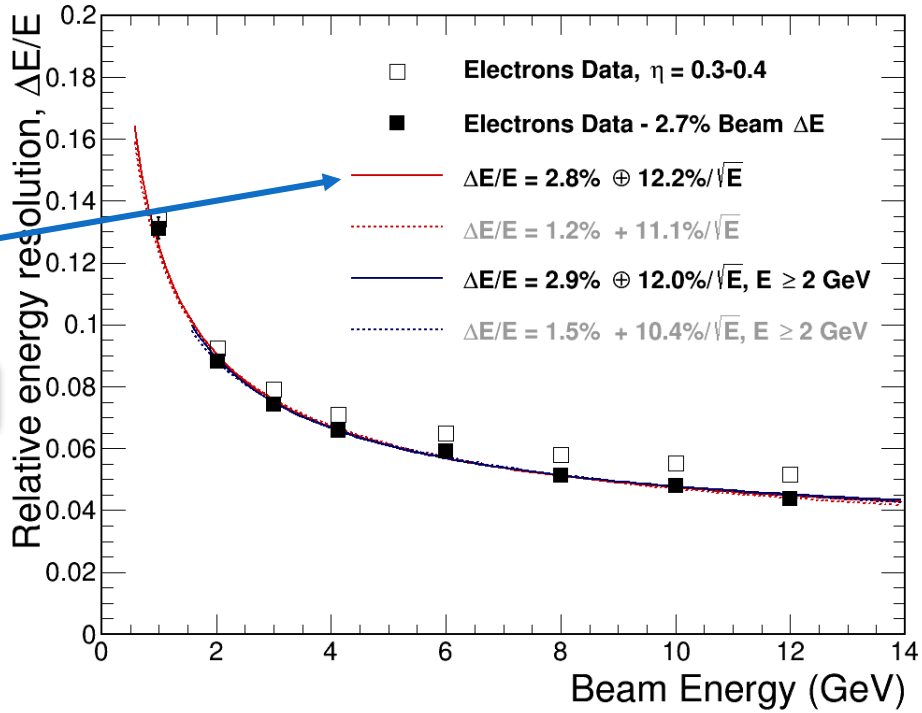
sPHENIX simulation,
1D projective EMCal only, full B

1GeV electron is B-bended by 0.45 rad
→ higher SF. and performance



Consistent perf. for EM shower

EIC RD1 study
FermiLab beam tests, 1D projective EMCal



Note difference in range of X-axis

Energy resolution inspections

Simulated on SPACAL without VTX and in full magnetic field

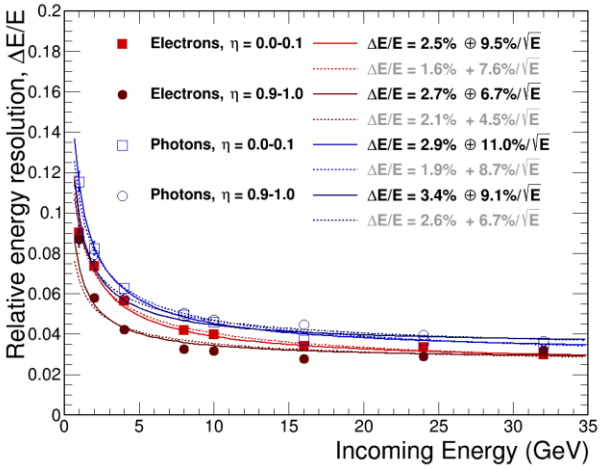
- 1GeV electron is bended by 0.45 rad → performance ~ photon w/ eta of 0.45 and view higher SF.
- **For EIC, Resolution ~< 12%/√E for electrons after magnetic field bending**
- **For sPHENIX, Resolution ~< 14%/√E for direct photons**

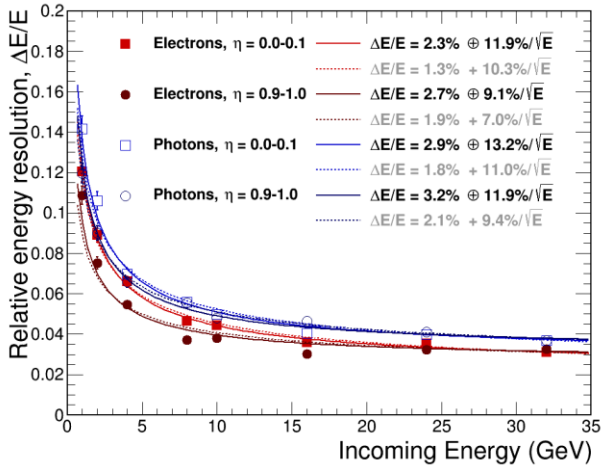
Sampling fluctuation
- 11%/√E for γ
- 9.5%/√E for e^- w/ B

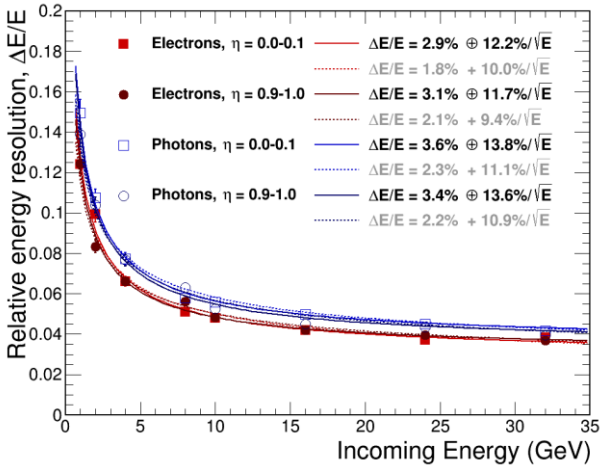
+ readout / clustering
- 13.2%/√E for γ
- 11.9%/√E for e^- w/ B

+ 2D SPACAL
- 13.8%/√E for γ
- 12.2%/√E for e^- w/ B

+ Silicon detector
- 13.5%/√E for γ







1D SPACAL, No SVX, Sum all tower

No photo-electron fluctuation/pedestal noise

1D SPACAL, No SVX,

Pedestal noise (2ADC), photon fluctuation (500e/GeV)

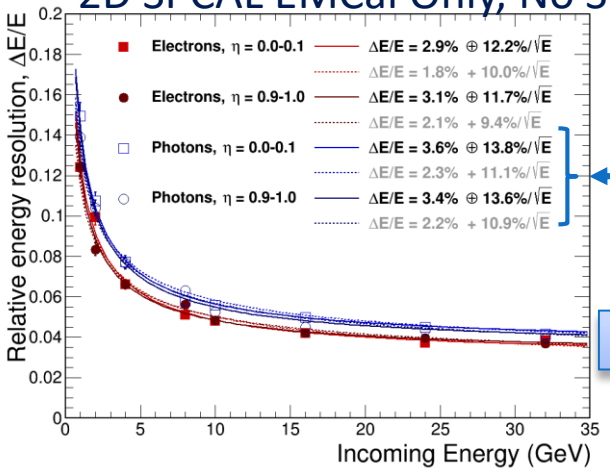
2D SPACAL, No SVX,

Pedestal noise (2ADC), photon fluctuation (500e/GeV)

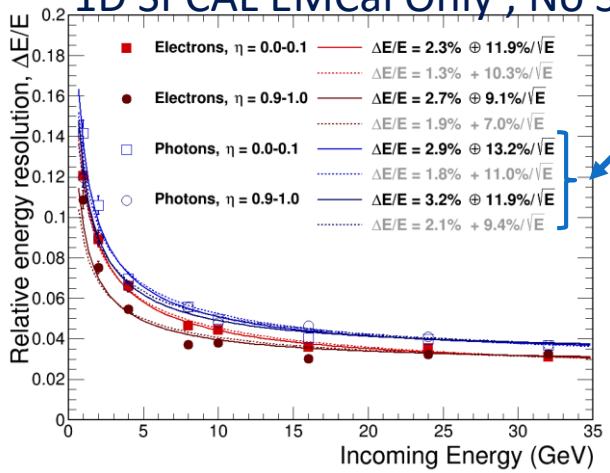
Energy resolution for full detector

Full detector Geant4 sim QGSP_BERT_HP + light yield model (Geant4 default Birk)
Pedestal noise (8pe), photon fluctuation (500pe/GeV), Zero sup (16pe), Graph clusterizer

2D SPCAL EMCal Only, No SVX

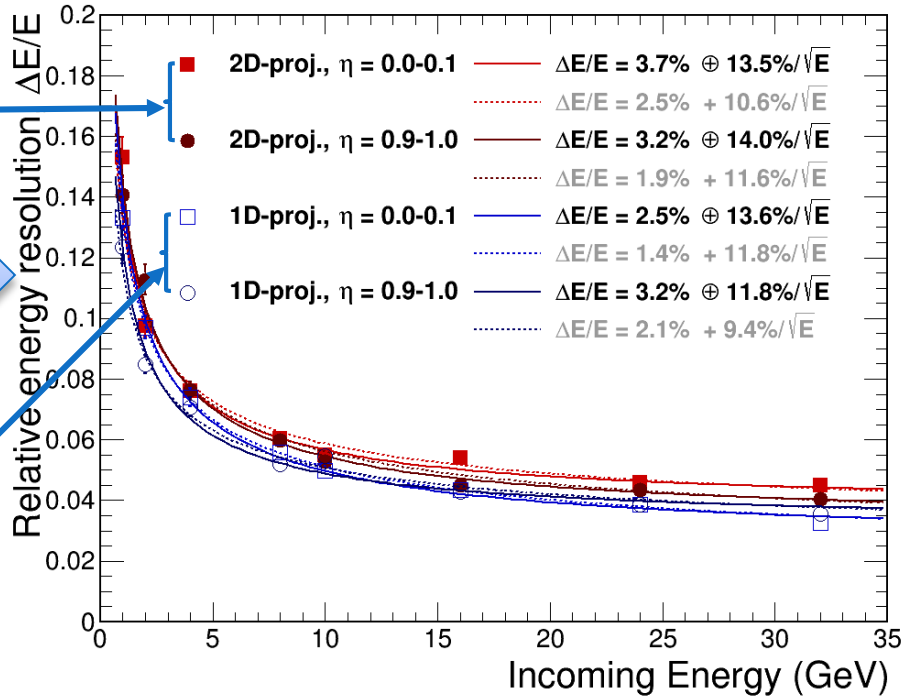


1D SPCAL EMCal Only , No SVX



+SVX

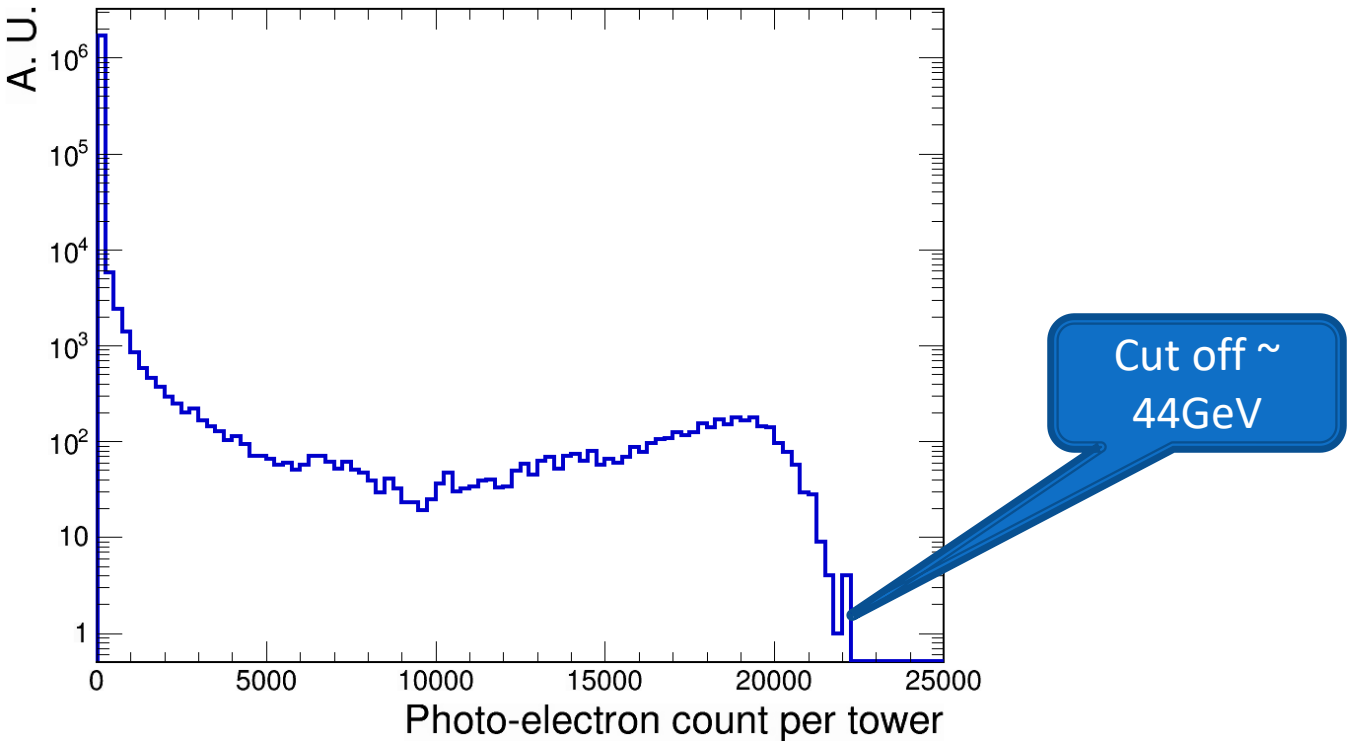
sPHENIX full detector single photon simulation



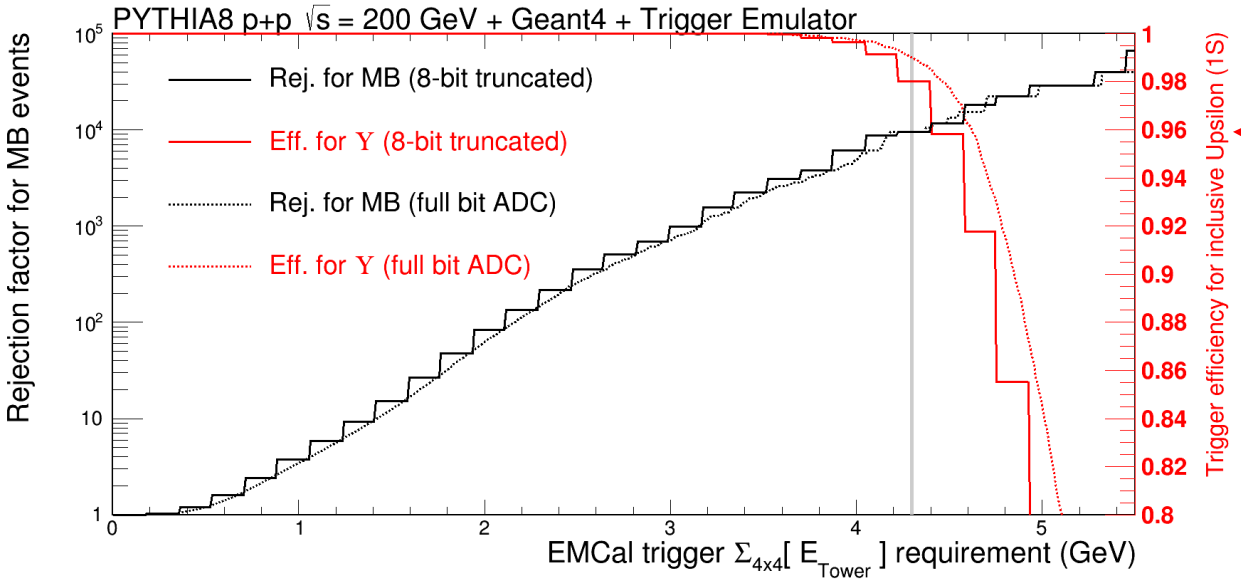
- Photon performance is similar with full detector (+10% X0 SVX before it)

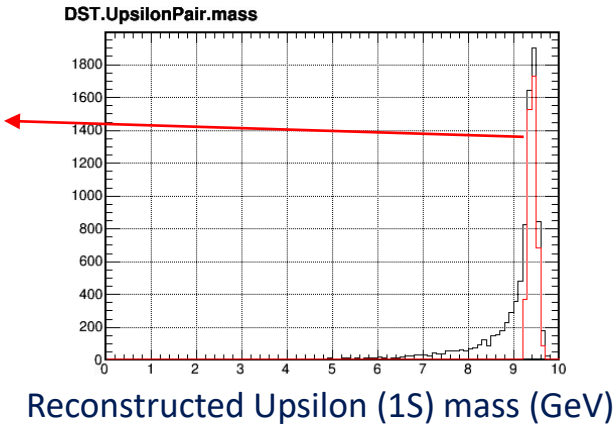
Dynamic range plot

50 GeV photon shower in 2D-projective SPACAL, all eta ranges
Plot photon observed per tower per event,
max ~ 22k photon/tower, pedestal σ~8 photon, range ~ 12bit (max/pedestal 1 σ)



Trigger efficiency – 2D SPACAL





Upsilon events required |eta_e|<1, reconstructed |mass – 9.6GeV| < 2 sigma

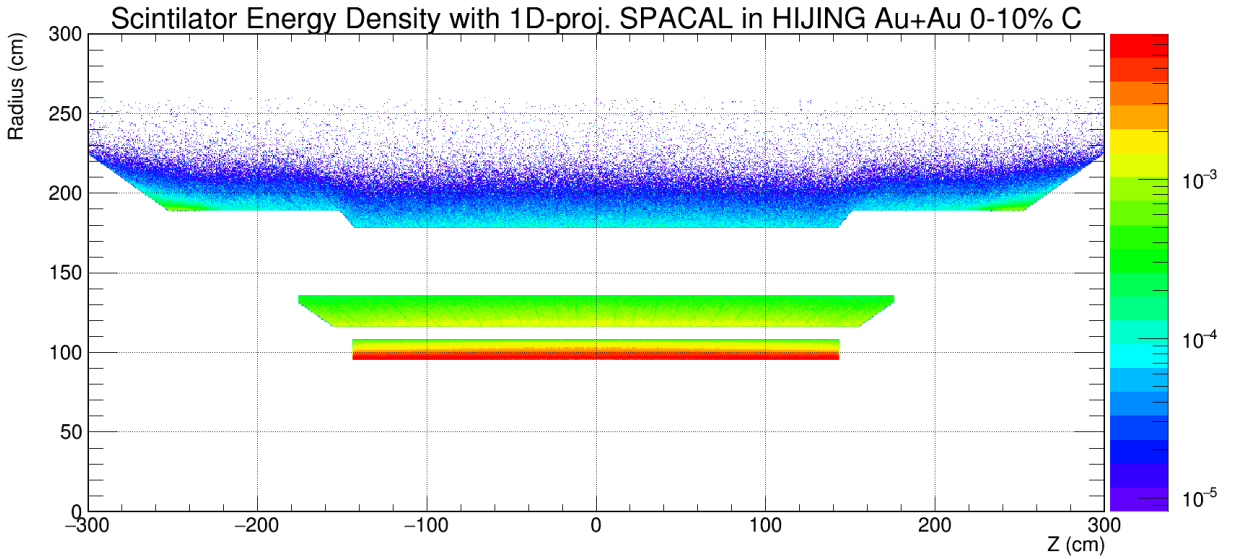
Result: ~10e4 rejection at ~98% efficiency

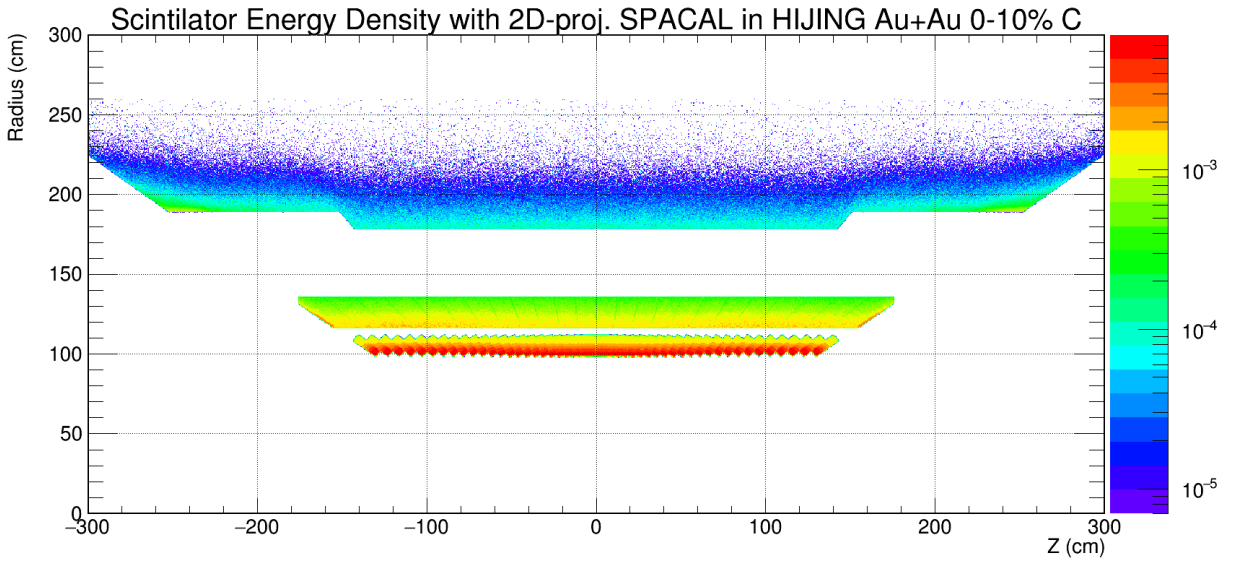
- Tail of Upsilon mass peak excluded for avoiding radiated photon, which are triggered with noticeably lower eff.
- Assumed trigger sum all combination of 4x4 towers, rather than sum of 2x2 → 4x4
- Realistic trigger would use reduced ADC bits, e.g. 8-bit. Performance did not significantly changed.
- 2D SPACAL showed. 1D SPACAL required larger cluster at the forward region

Geant4 sim QGSP_BERT_HP + light yield model (Geant4 default Birk)
Pedestal noise (8pe), photon fluctuation (500pe/GeV), Zero sup (16pe/32MeV), Graph Clusterizer

Occupancy in Hijing

- Volumetric energy density shown

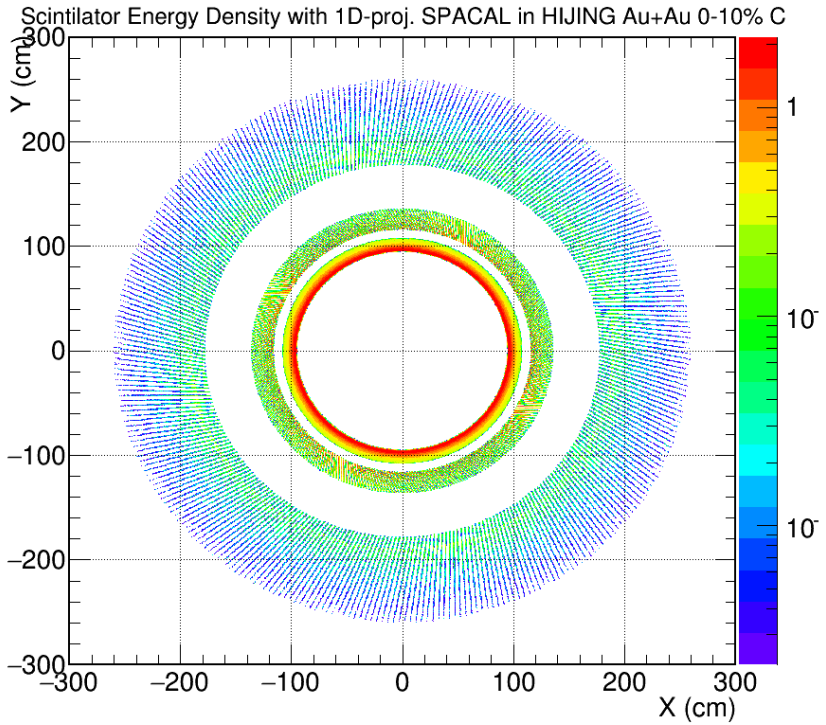


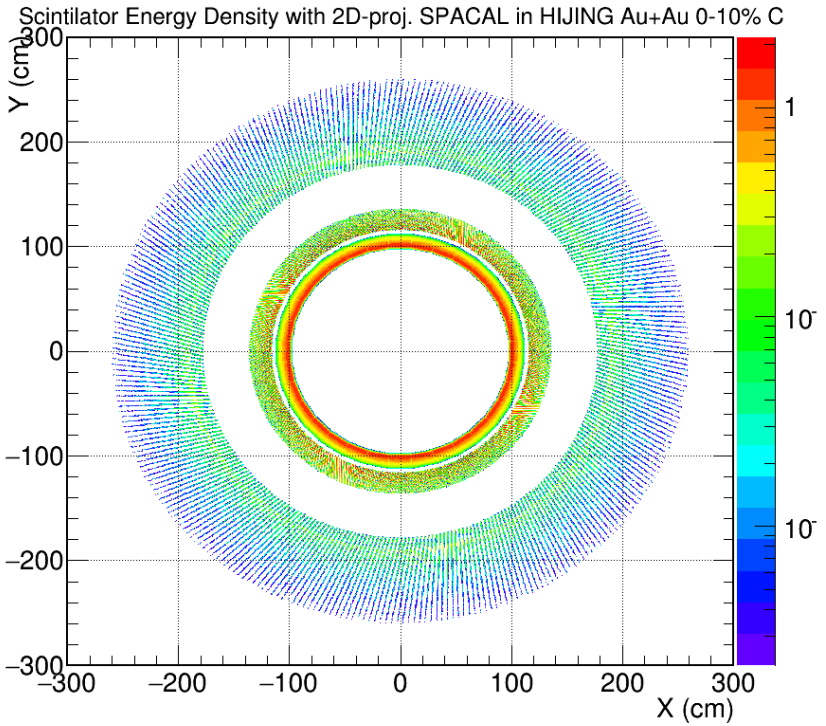


PHENIX

Occupancy in Hijing

2D energy density shown





1D Spacal

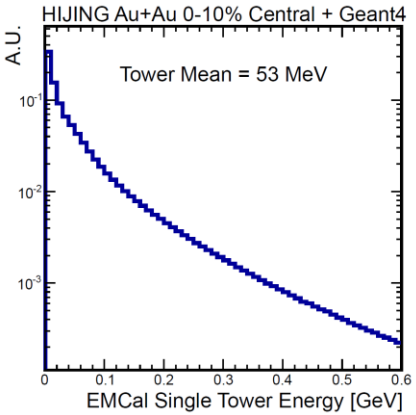
2D Spacal

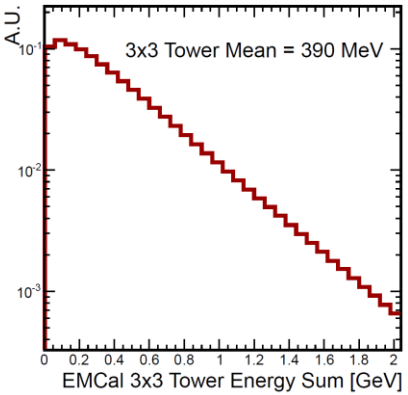
Occupancy – 0-10% Hijing

Geant4 sim QGSP_BERT_HP + light yield model (Geant4 default Birk)
Pedestal noise (8pe), photon fluctuation (500pe/GeV), Zero sup (16pe/32MeV), Graph Clusterizer

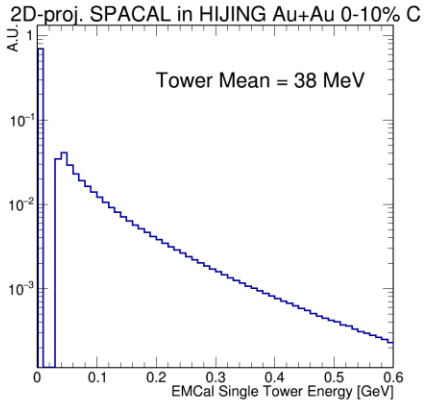
- Note the zero-suppression at 32 MeV.

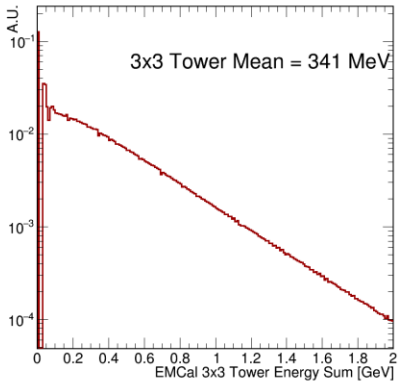
Scientific review (no digitalization, 1D proj.)

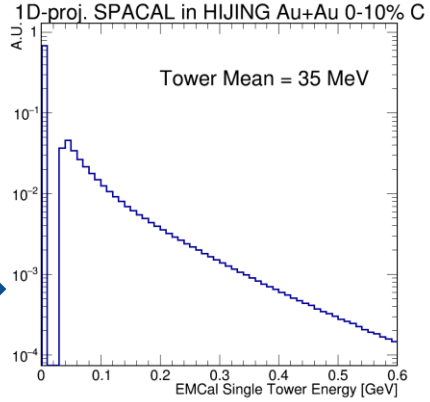


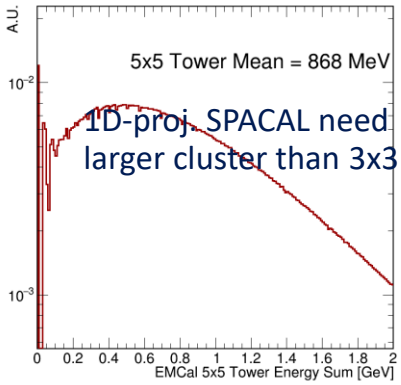


Realistic tower Digitalization









1D-proj. SPACAL need larger cluster than 3x3